Sheffield, Justin, Princeton University

Improved assessment of historical and future projected changes in global and regional drought

2010

Abstract:
Introduction to the Problem: In the U.S., the annual cost of droughts is about $5-8B. Globally, drought (and flood) losses have increased tenfold over the second half of the 20th century, to $300B. This is partly due to increases in population and wealth but may also be due to an increase in the number and severity of events that is only likely to get worse, given future climate projections. Detecting changes in extreme hydrologic events and their future risk relies on robust historic estimates of their occurrence. In its evaluation of changes in historic global drought, the latest IPCC Assessment Report (AR4) draws heavily from global analyses of the Palmer Drought Severity Index(PDSI), a simple modeled surrogate for soil moisture that is a popular drought monitoring tool. The PDSI shows a global decrease (increase in drought) in the last few decades that is attributed to global warming. However, the PDSI has a number of shortcomings because of its simplicity, which impact the depiction of trends. Of particular concern is its treatment of potential evaporation (PE), which is modeled as a function of temperature only and thus responds to recent observed warming, yet PE is also controlled by radiation, humidity and windspeed. A more realistic representation of evaporation is given by the Penman-Monteith (PM) algorithm, which accounts for both radiative and advective processes. Studies have shown that using the PM in calculations of PDSI at sites across Australia dramatically changed the trends in drought, which were sometimes of a different sign, mainly a result of decreasing windspeed. Our initial global simulations indicate how this effect manifests itself globally, with the decreasing trend in the original PDSI (and corresponding increase in drought) not apparent when using the PM formulation.
Rationale: These initial results show that the current IPCC assessment of global increase in drought is likely overestimated because of the reliance on a simplified model of drought that is over-sensitive to changes in temperature. Nevertheless, it is unclear what the true trend in drought is and whether increases in precipitation or other changes, such as increased snow melt, have offset the direct temperature effect. Given the wide-ranging policy impacts of such an overestimation and the remaining uncertainties, it is imperative that more robust estimates are made. We propose to evaluate the robustness of current estimates of changes in 20th century drought occurrence and develop improved datasets based on observation-forced, state-of-the-art hydrologic modeling, including the uncertainties, and use these to evaluate climate change projections. In particular we will focus on making robust estimates of 20th century global drought, and evaluate recent changes within the context of global warming and hydrologic cycle intensification. This work will leverage from the climate dataset development, global modeling and historic and future drought analyses carried out by the PI. These analyses have been cited in the

recent 3rd UN World Water Development Report and the forthcoming FY2010 USGCRP report to Congress.
Summary of work to be completed: 1. Evaluate the possible overestimation of global drought trends by the PDSI by comparison with more comprehensive estimates from observation forced hydrologic modeling. 2. Make improved estimates of historic drought based on our hydrologic modeling by using higher-quality regional meteorological data and extending back in time and updating to recent years. 3. Evaluate the uncertainties in drought reconstructions as derived from uncertainties in the climate forcings and the choice of hydrologic model. 4. Analyze these datasets in terms of changes in the occurrence and characteristics of drought and attribute change to the climate forcings and changes in the hydrologic cycle. 5. Evaluate CMIP5 simulations of historic drought and future projections against our hydrologic model based estimates and make improved projections through bias correction and downscaling.